"THERMO-MAN" FULL SCALE TESTS OF THE THERMAL PROTECTIVE PERFORMANCE OF HEAT RESISTANT FABRICS

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INTRODUCTION

The ability to predict the actual performance provided to the user from laboratory test results is often difficult but is always an important requirement of any laboratory procedure. Correct interpretation of test results is especially critical in the evaluation of thermal protective clothing where human responses are the measures of performance. The objective of these evaluations is reducing burn injury and saving of lives.

Correct thermal protection evaluation uses test conditions that are the best representation of the actual conditions experienced by the wearer. These must include a thermal exposure representative of the hazard, measurement techniques and interpretation of the heat transfer that relates to human tissue response, and physical/mechanical conditions that represent the protective garment configuration on the wearer.

The DuPont Company has developed an instrumented manikin, "Thermo-man" which is the best and most realistic test currently available to measure the thermal protective performance of garments. This technology will be shared with the University of North Carolina and will be one of the most important test procedures of their Thermal Hazards Laboratory.

METHOD

The important components of the "Thermo-man" thermal protection evaluation system are: 1. Generation of the thermal exposure, 2. Measurement of the heat transfer through the protective garment, and 3. Interpretation of the test results.

1. Test exposure. A major hazard in industry, fire fighting and the military service is a sudden, intense flash fire which can cause serious burn injury in one second or less. The intensity of these flash fires varies widely, but has been estimated to have temperatures approaching 2000 degrees F. and a heat flux that can reach 2.0-2.5 cal/cm2*sec. The body coverage and duration of the exposure depends highly upon the situation and can vary from a brief exposure of a small area of the body to complete immersion in flames for several seconds. The test heat flux is about 2.0 cal/cm2*sec and 8 torches are arranged so that flames cover about 85% of the manikin surface. These conditions with exposure durations of 3 to 6 seconds represent a serious thermal threat, and a challenge to protective clothing materials.

2. Heat transfer measurements. The heat transfer through the garment is measured to determine the effect of the exposure on the wearer, or in other terms, the protective performance of the garment. One way to accomplish this is to use animal tissue, exposed under a sample of the test material, and evaluate the amount and severity of the burn injury. This was the original technique, until sufficient data was collected to develop an understanding of the tolerance of human tissue to thermal exposure which can be used with thermal measurements.

The thermal evaluation techniques of the "Thermo-man" system use a sensor system that has some of the thermal inertial characteristics of human tissue and a computer program to estimate the location, amount, and severity of the burn injury. High temperature resistant sensors are uniformly located on the manikin surface to measure the heat transmitted through the protective garment. The heat flux is calculated which can then be used to calculate the temperature of human tissue at several depths. From the calculated time/temperature history of human tissue, and the known human tissue damage rate vs temperature, the degree and severity of burn injury that would occur in human tissue can be predicted from the manikin sensor temperature measurements. These data are summarized as the area and location of second degree, third degree, and the total burn injury which could be expected to result from a flash fire represented by the laboratory flash fire exposure.

3. Interpretation of results. Great care has been taken to develop a test procedure that can be used to realistically predict the performance of thermal protective clothing. The exposure is intense and representative of a real potential hazard and test conditions are carefully controlled. The thermal measurements are precise, and the burn injury predicted is based upon human tissue tolerance to heat. In addition, the manikin is life size, and full size garments are used as the test specimen. However, there are several concerns about the relationship of laboratory test data and actual performance. Differences in thermal exposure intensity, duration, or body coverage between the laboratory conditions and actual experience will affect the amount of protection actually provided. The protection performance is a measure of the total system tested, so any changes in fabric weight and garment fit on the wearer vs the manikin, will also change the actual protection provided by the test material. Finally, the "Thermo-man" test is a static test, and in a real thermal exposure, movement of the wearer to escape will add a mechanical force to the thermal situation.

RESULTS

The predicted performance of materials in the "Thermo-man" test range from over 90% total body burn area with flammable garments, to as low as 20-30% with flame resistant materials such as Nomex® and Kevlar® aramid fibers.

SUMMARY

The "Thermo-man" thermal protection evaluation system developed by DuPont has been used to develop improved thermal protective materials. It combines the key elements of a test procedure of a realistic exposure to garments on a life size manikin. The heat transfer is measured and compared to human tissue response to provide predictions of garnent protective performance. The College of Textiles at the North Carolina State University, using this technology, and other laboratory thermal protection tests, will be able to provide fundamental studies, graduate research programs, and thermal testing service to the textile and apparel industry. This work will provide the information for wider use, greater confidence, and further improvements of thermal protective clothing.